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ASSESSING FLOOD MAGNITUDE AND FREQUENCY. CASE STUDY: 2013 SPRING FLOODS ON THE JIU RIVER, FILIAȘI – CRAIOVA SECTOR (SOUTH-WEST ROMANIA)

EVALUAREA MAGNITUDINII ȘI FRECVENȚEI INUNDAȚIILOR. STUDIU DE CAZ: INUNDAȚIILE DIN PRIMĂVARA ANULUI 2013 PE RÂUL JIU, SECTORUL FILIAȘI-CRAIOVA (SUD-VEST ROMÂNIA)

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Abstract: The main objective of the study is to use the statistical models to analyse the probability of flood and the joint of temporal variability of the flood peaks and their seasonality. The case study refers to the 2013 spring floods on the Jiu River, Filiași-Craiova sector. Thus, in order to obtain several features of the maximum discharge, the maximum values, the increasing and decreasing time also the frequency of occurrence, one of largest floods is analysed. The data used were recorded at 3 hydrometrical stations on the Jiu River for a common period of 10 years.

The hydrological analysis is based on two methods of the maximum flow values: Mann-Kendal test and Gumbel distribution. In the first part, we have identified if it's a trend or not in the data series of the annual maximum discharge using Mann-Kendall trend test and the results were obvious, both statistically and graphically. The annual trend at two hydrometrical stations is of decrease (Test Z values: -1.58, Filiași hydrometrical station and -0.81, Răcari hydrometrical station), while at the hydrometrical station that closes the analysed sector is an increasing trend (Test Z value: 0.62, Podari hydrometrical station).

The Gumbel distribution is used to process the data from a long observation period of the maximum values. Applying this method to the flood data registered at the three hydrometric stations along the Jiu river are corresponding certain return periods (years) as follows: 1,140 cm/s registered at Filiași hydrometrical station has a 15 years return period; 1,447 cm/s reached at Răcari hydrometrical station has a 24 years return period; 1,309 cm/s recorded at Podari hydrometrical station has a 27 years return period. The above-mentioned values confirm the magnitude of the maximum flow at Răcari and Podari hydrometrical stations and anticipate the potential damage.

The flood frequency analysis using statistical models is important and also required in Romania given that the statistics of extreme events plays an important role in the engineering practice of water resources management.

Key-words: *floods, maximum flow, temporal trend, return period, the Jiu River*
Cuvinte-cheie: *inundaţii, debit maxim, tendinţă temporală, perioadă de reapariţie, râul Jiu*

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I. INTRODUCTION

1.1. National and international framework

Hydrological phenomena such as precipitation, floods, and droughts are inherently random by nature. Some of the floods and maximum flow parameters are stochastic in nature and are assumed to follow various probability distributions (Athanasios, 2002).

The trend analysis of hydrological series is of practical importance because of the effects of global climate change. Global warming has caused disruptions of hydrological cycles - a relevant example is found in the massive early spring stream flows resulting from accelerating snowmelt occurring in higher areas that supply rivers (Milly, 2005; Mote, 2003; Stewart et al., 2005; Paquini&Depetis, 2007).

Statistical procedures are used for the detection of the gradual trends over time. Criteria for selecting a frequency analysis procedure are discussed under two headings, descriptive ability and predictive ability (Hamed, 2008; Yue et al., 2002).

Regarding the future stream flow evolution in Romania it was found that flow trends over the past 50 years generally have downward evolutions during the spring and summer seasons, and upward ones during the autumn and winter seasons, which is mainly due to the countrywide climate change (Bîrsan et al., 2013).

The statistical analysis is used in Romanian hydrological research as follows:

- temporal trends of hydro-climatic variability in the lower Buzău catchment (annual, seasonal and monthly climatic and hydrological trends, using the non-parametric Mann-Kendall test, and the statistical significance of the r correlation coefficient was identified with the Bravais-Pearson test) (Mitof&Prăvălie, 2014);
- hydrological characteristics in the upper basin of Desnățui river (variations of monthly annual flows – Pearson III statistical test, the module coefficient, determining polynomial tendencies) (Velcu&Moroșanu, 2014);
- mean daily stream flow records from 44 river basins in Romania with an undisturbed runoff regime have been analysed for trends (the nonparametric Mann-Kendall test) (Bîrsan et al., 2013);
- cumulative frequency analysis with probability distribution and temporal variability using Mann-Kendall test within the Motru catchment area (monthly and annual maximum flow) (Ionuș&Dincă, 2013).

New distribution and estimation methods were introduced in the hydrologic software, some of them developed specifically for flood frequency analysis and their temporal trend. The present study aims to use two of them, relevant to the study area: Mann-Kendall test and Gumbel distribution.

1.2. Study area

The Jiu River is 65.7 km long on Filiași – Craiova sector (The Cadastral Atlas of Waters within Romania, 1992). The horizontal instability, obvious in the last 20 years in this sector, is explained by the type of alluvial transport and by the high erosion of the banks (Ionuş, 2014).

The hydro-geomorphological analysis of the Jiu valley in the Getic Piedmont sector is complicated because of the complex and varied relief, by the presence of numerous sand deposits in all levels, starting from the bottom of the river to the highest terraces (Savin, 1990).

The presence of the meanders along the Jiu river course are recorded in the right of Işalniţa and Coţofeni localities, here being the best preserved and most well developed meanders. In the village perimeter of Coțofeni the convolution coefficient a progressive/regressive dynamic from 1.85 (Savin, 1990) at 1.89/1.70 (GIS measurements performed on ortophotos, 2009).

There are numerous abandoned meanders in the Jiu floodplain due to straightening the course because of floods and cutting the meander loop.

On the analysed sector, defensive hydrotechnical works are represented by: bank defences and groynes (Schitu and Bâlta villages); watercourse regularization, Jiu's direct tributaries (Răcari, Argetoaia, Raznic and Amaradia); protective dikes on both banks, along the Jiu River, to defend farmlands and isolated objectives from its floodplain; Işalniţa accumulation lake, which besides mitigating flood waves has a role in water supply of Craiova municipality.

In the Işalniţa – Podari sector, the Jiu's general trend is to build its floodplain on the left side and to destroy the right bank by lateral erosion.

The settlements located in the floodplain and low terrace of the Jiu present differentially flood risk given by hypsometry, distance and effectiveness of built dams. Thus, downstream from Filiași the Jiu floodplain is well developed, with a maximum width of 3.8 km (between Braloștița and Răcarii de Jos; between Coțofenii din Față and Coțofenii din Dos). The altitude of where the villages are located varies from 45 m (Braloștița), 58 m (Scăieşti), 69 m (Coţofenii din Dos), on the right side of the river, and 92 m (Coţofenii din Faţă), 102 m (Răcarii de Jos) and 123 m (Brădeşti), on the left side of the river (Fig. 1). All these present a high risk of flooding (the elements at risk are farmlands and households), adding Scăieşti settlement situated near Răcari hydrometric station.

The distance of 5.1 km, between the Scăiești and Brădești settlements, in conjunction with Brădești's location on the lower terrace, denotes a low flood risk (elements at risk are only farmlands). Downstream Ișalnița Lake, Bucovăţ and Craiova settlements (located at a distance of 0.9 km) present a low risk to flooding, caused by the high slope of Bălăcița Piedmont on which Bucovăț village is located and by the protection of the dike (ensuring of 0.1%) built along the Jiu in the perimeter of Craiova municipality.

II. DATA AND METHODS

For the present study, there were used monthly and annual maximum flow values from three hydrometrical stations (h.s.) along the Jiu River: Filiași h.s., Răcari h.s. and Podari h.s. The datasets cover a 10 years period (2002-2011).

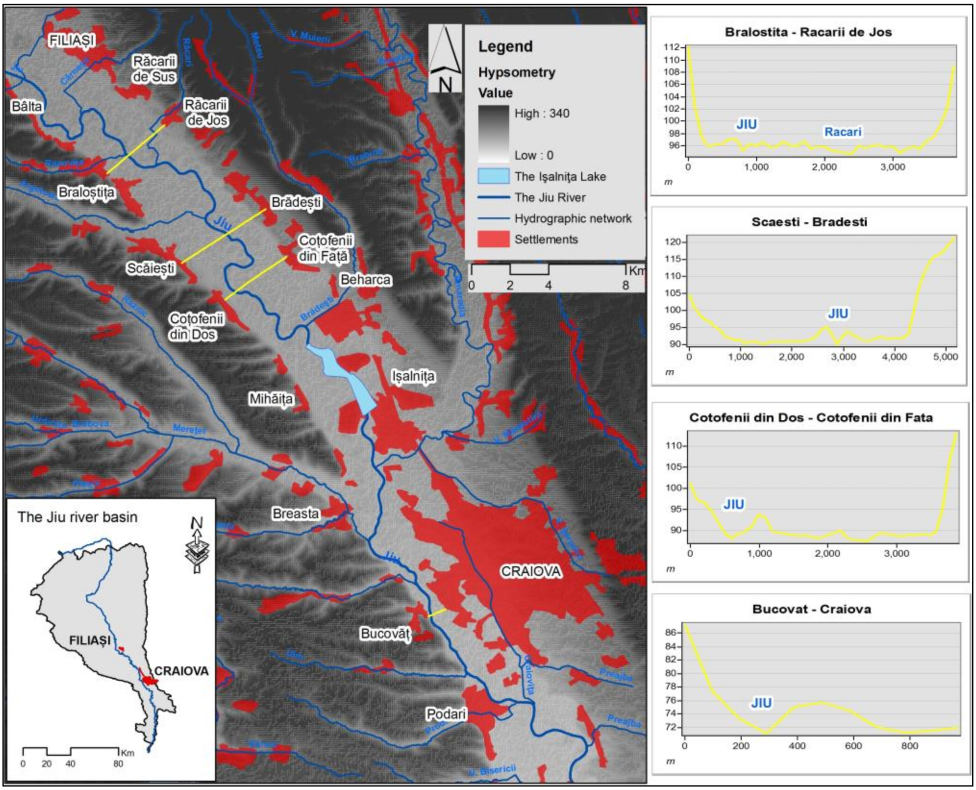


Fig. 1. The hypsometry of the Jiu River Valley in the middle course, Filiaşi – Craiova sector

In order to achieve the hydrometric analysis of the return periods of maximum discharge the maximum annual flow values recorded in 2012 and 2013 at Filiași h.s. and Răcari h.s. were added in the hydrological analysis. Regarding the assessment 2013 spring floods on the Jiu River (the case study of the research), we correlated the values of the water level and peak flow with the time of occurrence of floods at the three hydrological stations. All input data were provided by the ''Romanian Waters'' National Administration (ANAR) and the Jiu Water Branch (ABA Jiu). To detect trends in the time series of maximum flow, it was used the Excel template MAKESENS (Mann-Kendall test for trend and Sen's slope estimates), developed by the researchers of the Finnish Meteorological Institute (Mann, 1945 and Kendall, 1975 quoted by Gilbert, 1987). Mann-Kendall assesses whether a time-ordered data set exhibits an increasing or decreasing trend, within a predetermined level of significance. In MAKESENS the tested significance levels are 0.001, 0.01, 0.05 and 0.1 (Salmi et al., 2002). The 0.1 significance level means that there is a 10% probability that the values xi are from a random distribution and with that probability we make a mistake when rejecting H0 of no trend. Thus, the 0.1 significance level means that the existence of a monotonic trend is probable.

The flood magnitudes were analysed by using a software package named CumFreq: Cumulative frequency analysis with probability distribution; this statistical shareware program, which calculates the cumulative frequency and realizes probability fitting of data series, was developed by The Institute for Land Reclamation and Improvement (ILRI), the Netherlands. The distribution preference selected is Gumbel (Generalized Gumbel distribution), a particular method of the generalized extreme value distribution in hydrology (10 years period and 5 number of intervals). This model is tested and validated using observed flood data from the Jiu River and the output data can be easily represented on a histogram of fitted distribution by interval frequency (%). Results (statistical data and graphs) will indicate that the model is suitable for representing the joint distributions of flood peaks and volumes, as well as flood volumes and durations.

III. RESULTS AND DISCUSSIONS

3.1. Hydrological analysis

3.1.1. Flood statistics

Due to the cumulative effect of significant rainfalls recorded, water disposal from snow melting and propagation, there were significant increases in levels and flows on the Jiu River, which led to exceeding defence levels. On April, 3rd, 2013, the Jiu Rriver levels were increased by 155 to 267 cm, standing at 08.00 hours above:

- flood level (FL) at Filiași h.s. – level exceeded by 10 cm;
- danger level (DL) at Răcari h.s. - level exceeded by 11 cm;
- attention level (AL) at Podari h.s. - level exceeded by 75 cm.

The warning of the ‘‘Romanian Waters’’ National Administration (ANAR) continued on the Jiu River on 4 April 2013, as following: Filiaşi h.s., FL +52 cm; Răcari h.s., DL+115 cm; Podari h.s., DL+20 cm (Photo 1).

Photo no. 1. Increased water level along the Jiu River, Filiași (left) and Răcari (right) hydrometrical stations (Photo by Ionuș, April, 4th, 2013)

Considering that the volume of water discharge (a flood parameter), has not been calculated, the amplitude of this extreme events can be identified on one hand by the floods time parameters (Fig. 2, 3, 4 and Table no. 1), and on the other hand by the negative effects produced, specifically damages (see section 3.2).

Studying the flash-flood hydrographs occurred on the Jiu river between 1-18 April 2013, after the flash-flood timing and the general form of the graph given by the values of the recorded debits, highlights at all three hydrometrical stations a main peak: (Q max): 1,140 cm/s – Filiași h.s.; 1,147 cm/s – Răcari h.s.; 1,309 cm/s – Podari h.s.

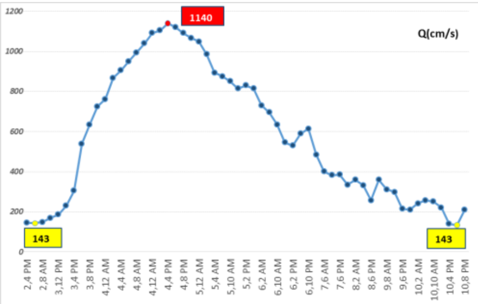


Fig. 2. The flash-flood hydrograph on the Jiu River recorded at Filiași h.s. (April, 2nd-10th)

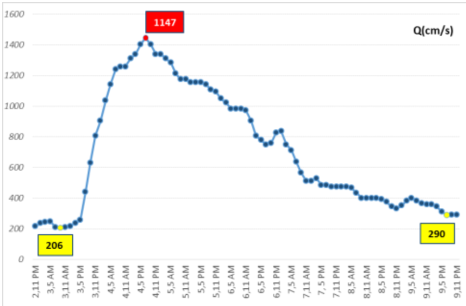


Fig. 3. The flash-flood hydrograph on the Jiu River recorded at Răcari h.s. (April, 2nd-10th)

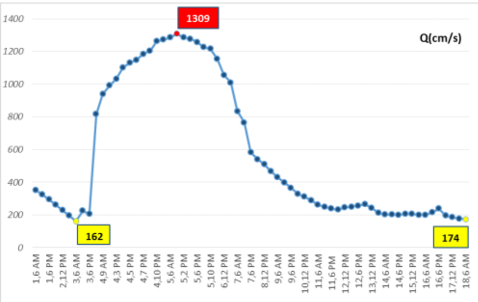


Fig. 4. The flash-flood hydrograph on the Jiu river recorded at Podari (April, 2nd-18th)

Table no. 1. The increasing and decreasing time of April, 2013 flash-floods along the Jiu River

H.s.	Qmax (cm/s)	Time	
		Increasing river discharge	Decreasing river discharge
Filiași	1,140	2 days	6 days, 4 h
Răcari	1,147	2 days, 8 h	5 day , 4 h
Podari	1,309	2 days, 6 h	13 days, 8 h

H.s. – hydrometric station, Q- maximum discharge

(Data source: ''Romanian Waters'' National Administration - the Jiu Water Ranch)

The temporal data that underlies the hydrographs of the occurred flash-floods highlights the mono-wave general form with light reminiscences of recovery after the main peak occurrence, respecting however the differences of size and the upstream-downstream location of the hydrometrical stations (triggering of the flash-flood occurred on the 3 April in all three hydrometrical stations).

Some shape imperfections of the characteristic hydrograph of Podari hydrometrical station is due to the influence of the Ișalnița Lake on the Jiu River flow and mitigation of the flash-flood waves.

Representative times (increasing, decreasing and total time) reflect the upstream-downstream ratio of the hydrometrical stations, and flow intake influence brought by its tributaries (Gilort River for Filiaşi h.s.; Motru River for Răcari h.s.; Argetoaia, Amaradia, Raznic and Tejac Rivers for Podari h.s.).

The total time of occurrence was for 8 days and 4 hours at Filiaşi h.s., 7 days and 12 hours at Răcari h.s. and 15 days and 14 hours at Podari h.s. The incresing time had similar values at all the three hydrometrical stations, from 2 days to 2 days and 8 hours. Instead, the lowest decreasing time was recorded at Răcari h.s. (6 days, 4 hours), which also anticipates significant damages corresponding to a flood caused by a flash-flood of this magnitude. The highest decrease time value corresponds to the Podari h.s. (13 days and 8 hours) which confirms the flooding of the upstream lands and the Ișalnița Lake effect on the Jiu River flow.

3.1.2. The temporal trend analysis - monthly and annual maximum flow

The existence of a trend in a hydrological time series is detected by Man-Kendall test. The first results displayed by the Excel template MAKESENS are the basic statistics associated with the time series (10 years).

The two values resulted of the trend analysis are Test Z (column F), statistical significances (column G) and Sen's slope estimate – Q (column H). We used more than 10 values for each hydrometrical station, so the test is based on the Z statistic (normal approximation) and for all trends the significance level is greater than 0.1 (column G is blank). A positive (negative) value of Z indicates an upward (downward) trend. In the case of monthly values the Mann-Kendall test takes into account the seasonality of the series and tries to find out if there is a trend from one month of April to another (from the 10 years period).

According to Mann-Kendall test combined with Sen's slope (Table no. 2), monthly and annual maximum flow trends are quite different. The annual trend at two hydrometric stations (Filiaşi and Răcari) is of decrease, while at the hydrometrical station that closes the analysed sector (Podari h.s.) the trend is of increase. The maximum flow values recorded in 12 months show an increasing trend at Filiași h.s. (8 cases out of 12) and Podari h.s. (10 cases out of 12).

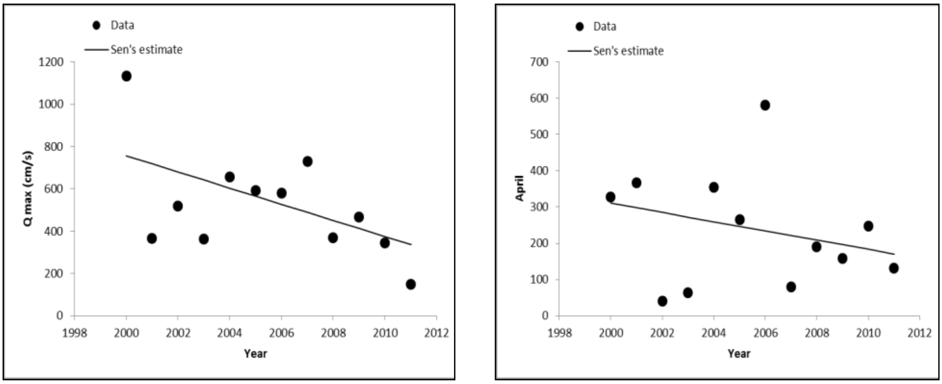
The trend at Răcari h.s. presents a special case because in January, February and March the trend is increasing, and afterwards, until the end of the year it is decreasing. The first three months of the year show the increasing trend due to location of the three hydrometrical stations at the end of the middle course of the Jiu River, upstream of the confluence with the main tributaries Gilort and Motru Rivers, in terms of transported water volumes affected by climate changes – mild winters and early snow melting. The decreasing trend characteristic to April confirms that the maximum flow values recorded in 2013 represent an exception of the trend at the temporal scale (Fig. 5).

The Mann-Kendall (M-K) Test is a simple test for trend. Mann-Kendall is a non-parametric test and as such, it is not dependent upon the magnitude of data and assumptions of distribution, for which we will refer in the next stage to the assessment of the floods magnitude, the frequency of value classes of the maximum flows and the return period of the peak flow.

Table no. 2. Characteristics of the maximum hydrological trends at annual and monthly scale at the three hydrometrical stations considered (values resulted from the application of Mann-Kendall test)

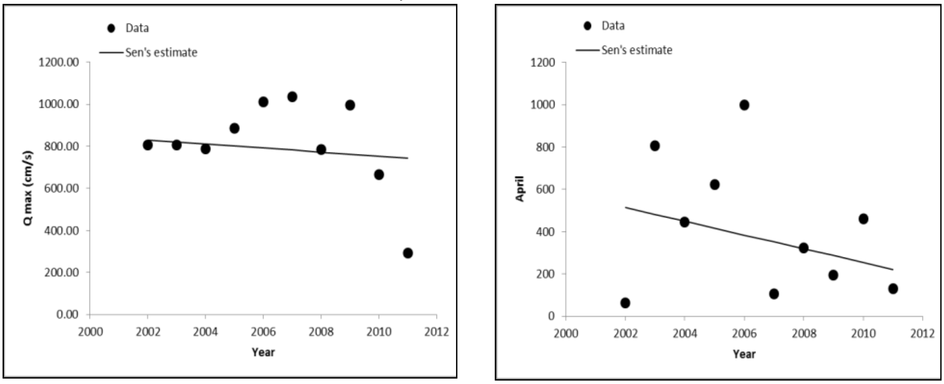
Temporal scale		Mann-Kendall test	River flow (cm/s)		
			Filiași	**Răcari**	**Podari**
ANNUAL		*Sen's slope*	-38.170	-9.500	28.675
		Test Z	-1.58	-0.81	0.62
		Trend type	down	down	**up**
MONTHLY	January	*Sen's slope*	8.702	10.350	18.546
		Test Z	1.44	0.89	1.58
		Trend type	**up**	**up**	**up**
	February	*Sen's slope*	10.663	10.167	12.5 4
		Test Z	0.75	0.54	1.03
		Trend type	**up**	**up**	**up**
	March	*Sen's slope*	-1.750	23.283	19.392
		Test Z	0.00	0.36	1.03
		Trend type	-	**up**	**up**
	April	*Sen's slope*	-12.700	-32.500	-19.763
		Test Z	-0.48	-0.36	-0.75
		Trend type	down	down	down
	May	*Sen's slope*	1.463	4.500	7.213
		Test Z	0.21	0.00	0.62
		Trend type	**up**	-	**up**
	June	*Sen's slope*	7.500	-1.600	6.836
		Test Z	1.17	0.00	1.30
		Trend type	**up**	-	**up**
	July	*Sen's slope*	2.837	4.200	3.510
		Test Z	0.55	0.00	0.48
		Trend type	**up**	-	**up**
	August	*Sen's slope*	0.194	-22.000	1.930
		Test Z	0.00	-1.07	0.41
		Trend type	-	down	**up**
	Sept.	*Sen's slope*	-7.336	-16.438	-1.710
		Test Z	-1.03	-1.43	-0.27
		Trend type	down	down	down
	October	*Sen's slope*	3.346	-14.000	2.155
		Test Z	0.48	-0.72	0.48
		Trend type	**up**	down	**up**
	Nov.	*Sen's slope*	10.850	-3.733	21.742
		Test Z	0.75	0.00	1.03
		Trend type	**up**	-	**up**
	Dec.	*Sen's slope*	14.790	-10.740	26.421
		Test Z	0.89	-0.54	0.62
		Trend type	**up**	down	**up**

Filiași hydrometrical station



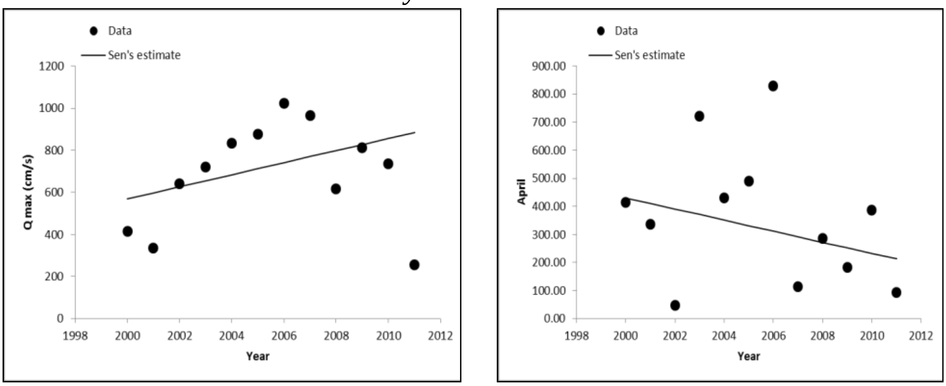
A **M**

Răcari hydrometrical station



A **M**

Podari hydrometrical station



A **M**

Fig. 5. Trends of the annual (A) and monthly (M) maximum flow along the Jiu River, for the 2000 – 2011 period (Mann-Kendall test results)

3.1.3. The cumulative frequency analysis with probability distribution – annual maximum flow

This statistical method is based on input data of the annual maximum flow (for the 2013 year this corresponds to the values of the peak flow analysed in section 3.1.1.) and covers 12 years (2002-2013 period) for Răcari h.s. and 14 years (2000-2013 period) for Filiași and Podari h.s. The output data can be easily represented on a histogram of interval frequency and on a graph with return period corresponding to the annual maximum values (Fig. 6). Observed and calculated cumulative frequencies of the annual maximum flow at the Filiași h.s. highlight four classes (< 150 cm/s; 150-649 cm/s; 650-1,140 cm/s; >1,140 cm/s), the interval with high frequency (62.4%) is represented by an annual maximum flow with a value between 150 cm/s and 649 cm/s. Maximum flow with a higher value than 1,140 cm/s (value registered in April 2013) has a frequency of 8.4%.

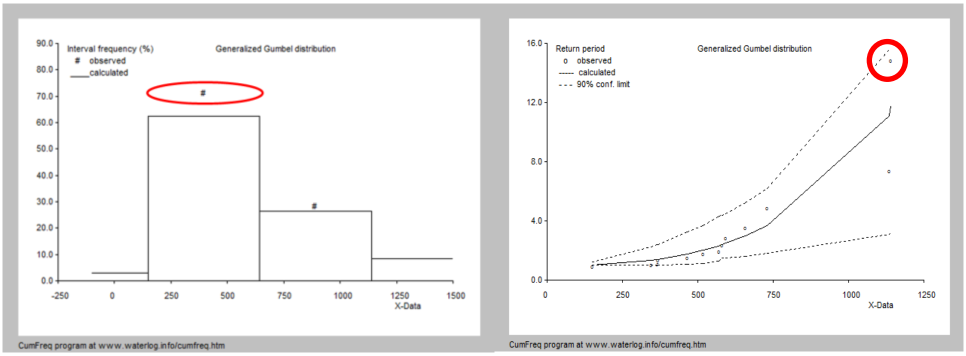


Fig. 6. Frequency analysis and return period of the maximum flow registered at Filiași h.s. in the 2002–2013 period

The frequency analysis of the annual maximum flow registered at Răcari h.s. shows similar values for two classes: 47.4% for 300-869 cm/s and 42.7% for 870-1,447 cm/s, which proves that the annual maximum flows with values between 300 cm/s and 1,447 cm/s were quite frequent in the analysed period (2002-2013) (Fig. 7).

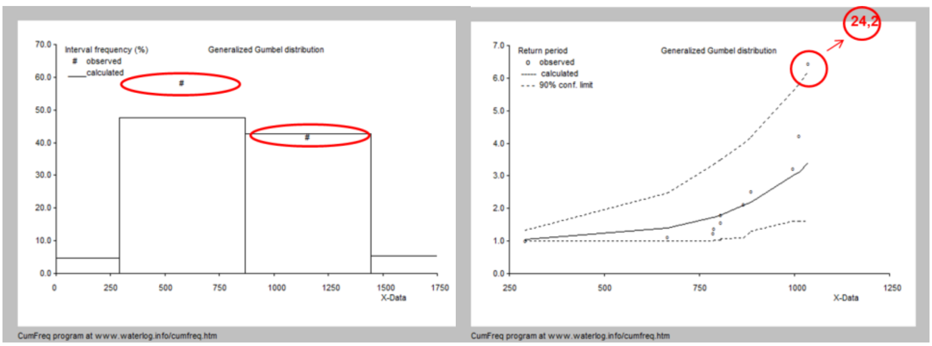


Fig. 7. Frequency analysis and return period of the maximum flow registered at Răcari h.s. in the 2002–2013 period

A similar case is recorded at Podari h.s. where out the four classes of values resulted from the analysis of the annual maximum flow frequency, the percentage of dominant belongs to only two of them: 250-780 cm/s with 46.5% and 781-1,309 cm/s with 39.6% (Fig. 8). The statistical situation presented at Răcari and Podari h.s. is a warning to the authorities in the field of water resources management, this sector of the Jiu River needing future anthropogenic intervention to reduce flood risk.

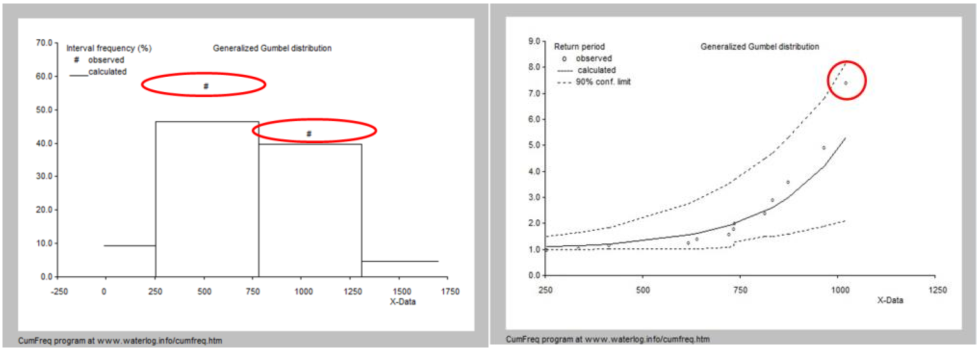


Fig. 8. Frequency analysis and return period of the maximum flow registered at Podari h.s. in 2002–2013

The applied method was statistically accurate because the efficiency coefficient (R) of calculated and observed cumulative frequency presents high values in the cumulative frequency function of the generalized Gumbel test: 0.9756 – Filiași h.s.; 0.937 – Răcari h.s.; 0.9836 – Podari h.s. The return period graph of the 2013 maximum flow and the formula used by the CumFreq programme, Return period = 1/(1-Cum.Frq), correlates the registered values with a certain return period (years) as follows:

- 1,140 cm/s registered at Filiași h.s. has a 15 years return period;
- 1,447 cm/s registered at Răcari h.s. has a 24 years return period;
- 1,309 cm/s registered at Podari h.s. has a 27 years return period.

The above-mentioned values confirm the magnitude of the exceptional values of the annual maximum flow at Răcari and Podari hydrometrical stations. If we analyse the return period of the annual maximum discharge at these two stations, we can observe major differences at a temporal scale between the values registered in April 2013 and November 2007 (1,036 cm/s with a 6 years return period) at Răcari h.s. and March 2006 (1,022 mc/s with a 8 years return period) at Podari h.s. It can be mentioned that from the viewpoint of the recurrence period the 1,447 cm/s of the annual maximum flow registered in April 2013 represents a special case of the statistically analysed sequence (2002-2013 period).

3.2. Socio-economic impact

The 2013 spring flood consequences vary depending on the magnitude of the event along the studied sector, and the vulnerability of the affected items. According to The Dolj County Inspectorate for Emergency Situations and to ANAR Press

Review (April, 4th, 2013 and April, 6th-8th, 2013) the most affected settlements by the Jiu River 2013 spring floods are: Bâlta (Filiași municipality), Răcari, Brădești, Coțofenii din Dos and Scăești.

At the beginning of the month April, the Jiu River broke the dam near the Beharca settlement, creating a natural breach that flooded the adjacent lands. The waters effused through the breach covered approximately 500 hectares of agricultural land and an uninhabited house.

On the Beharca-Tatomirești section, downstream of Răcari h.s., a second breach occurred with a length of about 7 meters – the dam was overflowed into two locations in lengths of about 20 meters. As a result of this breach there were agricultural land flooded (about 500 hectares), an uninhabited house and a pig farm, the animals being evacuated by the Inspectorate for Emergency Situations (ISU Dolj) crews. The ISU intervention consisted also in heightening the dam for stabilizing the natural breaches created.

The damages caused by the April 2013 floods upon the villages located along the Jiu River between Filiași and Craiova cities regard the following categories: agricultural land (562 ha, Braloștița and 525 ha, Scăiești); pasture (150 ha, Braloștița and 63 ha, Scăiești); forest (80 ha, Tatomirești and 40 ha Filiași); roads (1-Filiași, 1-Răcarii de Jos-Bralostița and 1 Coțofenii din Dos); households (15 in Filiași, 12 in Craiova and 2 in Coțofeni din Dos) (Table no. 3).

Table no. 3. The damages of the floods that occurred in April on the Jiu River, Filiași-Craiova sector

Settlement/ Category	Agricultural land (ha)	Pasture (ha)	Forest (ha)	Roads (no.)	Households (no.)
Filiași	**145**	**-**	**40**	**1 DJ 605A**	**15**
Răcarii de Jos	**125**	**50**	**20**	**1 DJ 606F**	**-**
Tatomirești	**160**	**50**	**80**	**-**	**-**
Bralostița	**562**	**150**	**-**	**1 DJ 606F**	**-**
Scaiești	**525**	**63**	**40**	**-**	**-**
Bradesti	**98**	**10**	**-**		
Coțofenii din Dos	**94**		**25**	**1 DJ 606A**	2
Leamna de Jos	**4**	**6**	**-**	**-**	**-**
Craiova	**-**	**-**	**-**	**-**	12

(Data source: ANAR, Press review – 4 April and 6-8 April 2013)

The roads that were flooded and closed from 2 to 8 April 2013 were: DJ 605A Filiaşi - Bâlta; DJ 606 A – Coțofenii din Dos; DJ 606F Bralostița -Răcarii de Jos, road flooded on a length of about 100 m, near the bridge that crosses the Jiu River (Photo 2).

Photo 2. The Jiu river flooded areas: Răcari settlement – agricultural lands (left), Cotofenii din Dos – country road DJ 606 F (right) (Photo by Ionuş, April, 4^{th}, 2013)

In Craiova 12 households were flooded on Fermierului street including the surrounding alleys and also another two streets: Petrila and Ecoului. This situation from the Jiu's floodplain was due to the remuu phenomenon produced by the Jiu River on the Abator stream, the dam imposing through its height and managing to protect the area from any damages (floods within the Mofleni neighbourhood).

The measures taken by the local authorities during the floods in order to reduce the damages were: the intervention crews of ISU Dolj and Local Water Management System (SGA Dolj) formed temporary sand deposits in Răcari-Scaieşti-Coţofeni area; police intervened by prohibiting drivers to cross the damaged roads. Local efforts were added to these interventions, for example, the inhabitants of Braloștița settlement tried to guide the bulging waters of the river through the channels to keep them away from the village. Therefore, it is necessary to propose further steps to be followed to reduce the risk of flooding on the Jiu River, Filiași - Craiova sector. A first category of measures aims hydro technical-works, more exactly the local reduction of the dam's levels to increase the connection frequency of minor/major river beds and the increase of the intra-dams distances within an area of mobility or function, or, in some cases, the total removal of the dam.

Information measures represent the second category and aims: greater involvement from municipalities by prohibiting construction in the floodplain; raising people's awareness that they live in a flood risk area. The third category is represented by the economic measures that may be imposed by: a greater involvement of local authorities (ABA Jiu and municipalities) by gaining/accessing funds to take the hydro-technical measures mentioned above; public or private insurances.

IV. CONCLUSIONS

This paper reveals some interesting aspects of the hydrological data (maximum flow) relation during flash-floods that could be important for estimating flood frequencies and flood forecasting.

The two methods (Mann-Kendall test and Gumbel distribution) applied in the hydrological analysis of the Jiu River have identified significant changes in the statistical parameters of the analysed records – annual maximum flow.

The results can be summarized in a few key conclusions:

- ✓ the trend of the maximum flows recorded at Răcari hydrological station presents a special case because in January, February and March the trend is of increase, and afterwards, till the end of the year it's of decrease;
- ✓ at period level, April shows the reduced tendency to record the maximum flows, the year 2013 being an exception, and the best correlation of the values for this month is at Filiași hydrometrical station;
- ✓ the return periods for maximum flows recorded at Răcari (1,447 cm/s) and Podari (1,309 cm/s) hydrometrical stations are large enough - 24 and 27 years, which approaches these values to some historical ones;
- ✓ the settlements with significant damages - Bâlta (Filiaşi municipality) Răcari, Brădeşti, Coţofenii din Dos and Scăeşti - are located along the Jiu upstream of Răcari hydrometrical station, the station that recorded the highest value of the maximum flow in April 2013 (1,447 cm/s) and the shortest decreasing period (5 days and 4 hours).

The 2013 spring flood assessment confirms once again the fact that in order to reduce the risks, it is highly necessary to have a detailed analysis not only of the hazard itself, but also of the land and human vulnerability. In this term, in the future, the local authorities need to develop a good plan of actions within the hazard-prone areas which involve low cost with maximum results.

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